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BASF Corporation
Wyandotte, Michigan

Sediment Characterization/ Remedial Evaluation Final Interim Measures Work Plan

BASF North Works

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ANOVA	analysis of variance
AOC	Administrative Order on Consent
BBL	Blasland, Bouck & Lee, Inc.
DQO	data quality objective
GOF	goodness-of-fit
MDEQ	Michigan Department of Environmental Quality
NOAA	National Oceanic and Atmospheric Administration
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RTK GPS	Realtime Kinematic Global Positioning System
SPI	Sediment Profile Imaging
SOP	Standard Operating Procedure
sVOCs	semi-volatile organic compounds
TOC	total organic carbon
USEPA	U.S. Environmental Protection Agency
XRD	X-ray diffraction
XRF	X-ray fluorescence

1. Introduction

On February 24, 1996, the U.S. Environmental Protection Agency (USEPA) issued an Administrative Order on Consent (AOC) for the BASF North Works property (the Site) located in Wyandotte, Michigan (USEPA 1994). The AOC identifies activities to be completed in accordance with the Resource Conservation and Recovery Act (RCRA). Presently, a variety of products are manufactured at the Site and the property has been utilized for various manufacturing purposes for more than a century. The Site encompasses approximately 230 acres along approximately 1.1 miles of the shoreline of the Trenton Channel of the Detroit River in the City of Wyandotte, Michigan (see Figure 1). The Site shoreline consists of sections of a steel sheet pile bulkhead along the northern portion of the Site extending southward; followed by a concrete seawall on a wood-pile wharf, and heavy rip-rap along the southern-most portion. Water depths at the shoreline range from approximately 3.2 feet to 31.5 feet.

As part of Site investigation activities pursuant to the AOC and USEPA-approved work plans (ARCADIS BBL 2007a; ARCADIS 2008b) and with oversight by USEPA and/or Michigan Department of Environmental Quality (MDEQ) personnel, BASF has conducted aquatic sediment probing and sampling activities adjacent to the Site (Along Site) and in upstream reference areas (Upstream) to assess the presence of sediments, constituent concentrations in the sediments, and relative differences between Along Site sediment quality and Upstream sediment quality. Information and data from the investigations completed to date have been presented in several reports (BBL 2006; ARCADIS BBL 2007b; and ARCADIS 2009). Results of the investigation and proposed next steps were presented to USEPA and MDEQ (the Agencies) on March 19, 2009 at USEPA Region V offices in Chicago. Results indicate concentrations of many constituents in Along Site sediments are in line with concentrations in sediments in Upstream reference areas; however, elevated pH levels were detected in sediments with field measurements on Along Site core samples ranging from pH 6.36 to 11.90 standard units[1]. Upstream sediment pH values range from 6.94 to 10.51. BASF proposed and discussed with USEPA several additional data collection activities and an associated schedule to address data gaps, as necessary, to better understand the extent of elevated sediment pH levels along the Site and the potential risks posed by Along Site sediments—as well as to collect data with utility for evaluation and design of potential remedial measures, if needed. BASF's

[1] All pH values in this Work Plan are measured in standard units

proposed approach was to collect those data and then to meet with USEPA to discuss options and next steps.

Subsequent to BASF's presentation, USEPA requested that BASF prepare an Interim Measures Work Plan to address Agency concerns about elevated pH levels in certain Along Site sediments (USEPA 2009a); sediments with elevated pH were observed in the southern Along Site area, specifically from sampling Transect 19 through Transect 29 (T19 through T29; see Figure 2). However, Transect 17 and Transect 18 were not previously investigated due to the undetermined location of a pipeline in the vicinity of these two transects. The portion of the Site from approximately Transect 16 on the upstream end to Transect 29 on the downstream end is defined as the Study Area and is the focus of this *Sediment Characterization/Remedial Evaluation Interim Measures Work Plan* (IM Work Plan). This IM Work Plan reflects the technical discussions BASF had at and since the March 19, 2009 meeting in Chicago, including feedback on a draft of this document provided during teleconferences on July 1 and July 8, 2009 and in a letter from USEPA to BASF dated July 17, 2009 (USEPA 2009b).

1.1 Interim Measures Work Plan Overview

This IM Work Plan has been prepared to support the identification and implementation of appropriate measures to address sediment contamination along the Site, including elevated sediment pH levels. This IM Work Plan was prepared with consideration of USEPA's Contaminated Sediment Remediation Guidance (USEPA 2005); the AOC for the Site (USEPA 1994); USEPA's April 24, 2009 letter to BASF (USEPA 2009a); BASF's proposed path forward discussed with USEPA on March 19, 2009 in Chicago; teleconferences on July 1 and July 8, 2009; USEPA's July 17, 2009 letter to BASF (USEPA 2009b); and professional experience gained through investigation and management of sediments at similar sites. The principal elements of this IM Work Plan are the field sampling activities necessary to fill key data gaps; the identification and evaluation of remedial measures; and the recommendation of appropriate measures in consultation with USEPA and MDEQ. A schedule for these activities is included (Figure 3). Additional separate IM subplans (e.g., IM Design Work Plan) may be developed concurrently with the implementation of this IM Work Plan and will be dependent on the results of the implementation of this IM Work Plan. When identified, the schedule will be amended to reflect the changes.

The basis for evaluation of alternative measures to address sediment concerns is anticipated to include an assessment of the extent to which elevated pH values in the river sediments may affect biota and overlying surface water quality. The basis for the identification of specific alternatives will include the delineation of the extent of sediments with elevated pH, the thickness and distribution of Along Site sediments, and the physical features of the sediments and the shoreline. This information is to be compiled through the investigation components of this IM Work Plan.

The schedule presented in this IM Work Plan (Figure 3) identifies the estimated period for design and approval of necessary planning documents. Specific design activities and a more detailed schedule will require identification and selection of a preferred alternative. The further refinement of the schedule will be completed in collaboration with USEPA and MDEQ as alternatives are developed and reviewed with the Agencies.

1.2 Summary of Supplemental Investigation Work

This IM Work Plan describes the objectives and procedures for supplemental data collection to be conducted in the Study Area (from T16 to T29; see Figure 2) in the Detroit River adjacent to the Site, which includes the following major activities:

- Hydrographic survey including multi-beam sonar bathymetry, side-scan sonar mapping of the sediment surface features and texture, and magnetometer readings.
- Collection of additional sediment cores for visual observation and field pH measurement to more accurately describe the pH distribution and depth to clay in the Study Area.
- Chemical analysis of additional cores obtained from select locations on existing transects beyond 100 feet from shore (i.e., outside the limits of prior sampling).
- Evaluation of sediment geochemical composition.
- Sediment Profile Imaging (SPI).
- Assessment of the benthic community and the biologically active zone conditions.
- Measurements of near-bottom surface water pH and measurement of sediment-water interface pH.

The planned investigative activities were prepared utilizing USEPA Data Quality Objectives (DQO) Planning Process Guidance and with consideration of Federal and State guidance for sediment sampling and analysis methods (e.g., USEPA 2006). The activities described in this IM Work Plan will be conducted in accordance with the USEPA-approved Quality Assurance Project Plan (QAPP) for North Works (Environmental Science & Engineering, Inc. 1996) and the addendum prepared for sediment investigation work (ARCADIS 2008a). The QAPP will be reviewed prior to field work and amended for USEPA approval, as appropriate, to include proper quality assurance/quality control (QA/QC) procedures related to benthic community sampling. The activities described will also follow proper data management practices in accordance with the RCRA Facility Investigation (RFI) Data Management Plan (QST Environmental 1996).

1.3 Document Organization

The remainder of this document is organized as follows:

- Section 2 provides more detailed project background information;
- Section 3 describes proposed field activities;
- Section 4 outlines considerations in the evaluation and selection of remedial alternatives;
- Section 5 describes reporting;
- Section 6 identifies the document repository for public participation;
- Section 7 provides a proposed schedule of activities; and
- Section 8 lists references used in preparation of this IM Work Plan.

2. Project Background

2.1 Site Description

The Site (Figure 1) is an active industrial facility approximately 230 acres in size located in Wyandotte, Michigan, adjacent to the federally maintained Trenton Channel of the Detroit River, downstream of the industrial centers and the urban center of Detroit. The Site shoreline, approximately 1.1 miles in length, consists of a sheet pile bulkhead (3442 feet), concrete seawall on a wood pile wharf (1503 feet), and rip-rap (824 feet). Water depths along the Site shoreline range from 3.2 to 31.5 feet and average approximately 20 feet. A history of the industrial processes occurring at the Site is included in Section 2.2 of the RFI Report (QST Environmental 1999) while details of filling, waste handling, and disposal methods are found in Section 3 of the RFI Report.

2.2 Summary of Phase I Investigation

The Phase I Sediment Probing Study was conducted in August 2007 along 29 regularly-spaced transects along the Site. Probe-able sediment depth measurements (defined as the total depth to which a calibrated rod penetrates sediment by normal hand pressure) were collected at up to 7 locations per transect, out to a distance of 100 feet from the shoreline. Results of the Phase I investigation (ARCADIS BBL 2007b) indicate a limited area of probe-able material along shore in Transects 01, 02, and 03, and a larger area with greater extent of probe-able sediments downstream of Transect 18.

The northern area of the Site, upstream of Transect 15, displays minimal thicknesses (typically less than 1 foot) of probe-able sediment with the exceptions of Transects 01, 02, and 03 where maximum probe depth between 20 and 50 feet from shore varied from 2.9 to 6.9 feet (core samples collected from this area in Phase 2 indicate probe-able materials include native soft clay underlying sediments; minimal sediment thickness was observed in core samples). Ponar samples collected in this area indicate sediment types are predominately coarse grained, with a number of sample attempts yielding no recovery.

The southern area of the Site, downstream of Transect 18, has probe depths greater than 1 foot in most locations. Each transect from Transect 18 to Transect 29 had 1 foot or more of probe-able material at 100 feet from shore. Ponar samples collected in this area indicate the presence of sand and silt material.

A report detailing the results of the August 2007 Sediment Probing Study was submitted to the Agencies for review on September 25, 2007 (ARCADIS BBL 2007b).

2.3 Summary of Phase II Investigation

The *North Works Phase II Sediment Investigation: Core Collection and Analysis Work Plan* (Phase II Work Plan) (ARCADIS 2008b) was developed based on the probe-able sediment thickness data collected along the Site shoreline during the Phase I Sediment Probing Study (ARCADIS BBL 2007b), targeting areas where significant sediment depths (i.e. probe-able thickness greater than 2 feet) were identified. The principal objective of the Phase II Investigation was to assess sediment quality Along Site and from Upstream reference areas to assess if discernable differences are present and if further sediment assessment is necessary. Sediment cores were collected from 34 locations on 11 Along Site transects and from 28 Upstream locations. One hundred forty-four samples from Along Site locations and 89 samples from Upstream locations were submitted for chemical analysis.

Sediment cores collected along the northernmost portion of the Site (Transects 01, 02, and 03) recovered very little sediment. Where previous probing depths were greater than 2 feet (i.e., during the Phase I Sediment Probing Study), vibracores recovered mostly native clay material. Soft probe-able clay falsely indicated a sediment deposit along the northern portion of the Site.

Sediment recovery along the southern portion of the Site (Transects 19 through 29) ranged from 1.9 to 9.5 feet, with an average of 5 feet, indicating a substantial sediment deposit. Field pH measurements in this area averaged 10.17 and ranged from 7.37 to 11.90. Generally, pH increased with sediment depth and was elevated where white/light gray silt material was present. This white material was present in 10 out of 29 cores collected in this area, including 6 of 7 cores collected at a distance of 100 feet from the shoreline. The full extent of the sediment deposit and white material present along the southern area of the Site are yet to be determined. By comparison, Upstream sediment pH values ranged from 6.94 to 10.51.

The results of chemical analyses and the statistical comparison of Upstream and Along Site sediment quality for the majority of constituents support a hypothesis that Along Site sediments are part of a continuum of degraded sediment quality extending from upstream areas. For some constituents, the statistical analysis (i.e., comparison to background screening levels and hypothesis testing) indicates possible incremental impacts in Along Site sediments. The upper tail of the distribution of 13 constituents in Along Site sediments, including five metals and eight semi-volatile organic compounds (sVOCs), appears elevated relative to Upstream sediments; however, the central tendencies of the distributions are consistent. The higher values of some sVOCs typically occur in the surface layer and may reflect influences of recent upstream sources. For four constituents (beryllium, pH, total cyanide, and phenol), both the central tendency and upper tail of the distribution of concentrations from Along Site sediments appear elevated relative to Upstream sediments.

The *Phase II Sediment Investigation: Data Summary Report* (ARCADIS 2009) detailing the results and findings of the investigation was submitted to the Agencies for review on March 31, 2009.

2.4 Exposure Pathway Considerations

A principal concern of the Agencies with the results of the Phase II Investigation has been the elevated pH levels in certain sediments. Site-specific conditions govern the potential human and ecological receptor exposure pathways to these sediments, and are summarized here. No direct human exposure pathways are present at the Site due to the following conditions:

- Water depths are approximately 20 feet on average along the shoreline due to the presence of the seawall and bulk head structures.

- The entire shoreline is fenced and no public access is permitted.

- River conditions in this area are not conducive or desirable for recreational activities such as wading, swimming, or SCUBA diving.

Ecological exposures are limited primarily to benthos that may inhabit the sediments and fish that may forage in the sediments. The shoreline characteristics and water depths that average approximately 20 feet essentially preclude direct contact by avian, mammalian, or other potential ecological receptors over most of the Site.

It is currently unknown whether elevated pH levels detected in deeper sediments are also present within the biologically active zone at the sediment-water interface. A portion of the activities in this IM Work Plan are designed to address this data gap.

2.5 Purpose

The sediment characterization activities presented in this IM Work Plan are intended to collect data to supplement data collected through the Phase I and Phase II Investigations. The supplemental data are being collected for purposes of completing risk evaluations, identifying alternative remedial measures, and supporting selection and implementation of an appropriate interim measure. Together, these data will support evaluation of various remedial alternatives and selection of the final corrective measures for sediments with elevated pH.

The primary goals of this IM Work Plan are to:

- Further define physical characteristics of sediment deposits along the Site from Transect 16 south to Transect 29 (Study Area).
- Further delineate pH values in sediments in the Study Area.
- Evaluate physical, biological, and geochemical conditions at the sediment-water interface in the Study Area.
- Evaluate the benthic community in the Study Area and reference areas.
- Provide additional sediment chemical analysis in the Study Area outside bounds of existing Phase II Investigation cores.
- Identify and evaluate various remedial alternatives.
- Identify the appropriate alternative to address sediments with elevated pH.

Following submittal and Agency concurrence with the IM Report to be prepared and submitted at the collusion of this effort, an IM Design Work Plan will be prepared and submitted to the Agencies. The IM Design Work Plan will carry forward and facilitate the design and implementation of the selected alternative as an interim measure to address sediment contamination along the Site.

2.6 Objectives of IM Investigation Program

The objectives of the IM Work Plan investigation program described in Section 3 are to:

- Measure bathymetry throughout the Study Area using hydrographic survey methods.
  - In conjunction with bathymetric survey, side-scan sonar imagery may be obtained to gather additional sediment bed characteristic information, and a magnetometer survey may also be conducted to locate metallic objects submerged or buried beneath the sediment surface.
- Collect additional sediment cores and probing information to refine sediment thickness and top of clay elevations within the Study Area.
- Identify the extent and nature of pH values in sediments in the Study Area.
  - Collect sediment cores and probing information to determine sediment thickness and top of clay elevations from Transect 16 to Transect 19 to quantify pH values in Along Site sediments, including beyond the Phase II Investigation 100-foot sample locations.
  - Quantify pH values in sediments in the offshore direction beyond the existing Phase II Investigation 100-foot stations.
  - Collect and analyze core samples in the Study Area. Samples will be collected outside the limits of data at approximately the same per-acre sample density as Phase II Investigation cores.
- Collect data to evaluate conditions at the sediment-water interface using the following methods:
  - Collect SPI of the sediment-water interface within the Study Area and reference areas to characterize sediment types and map changes in the sediment bed.
  - Collect near-bottom surface water pH measurements at approximately 8 to 10 locations within the Study Area.
  - Collect sediment-water interface pH readings at approximately 8 to 10 locations within the Study Area using multi-sensor Trident probe technology.

    - Collect and analyze select sediment samples for geochemical characterization to determine specific mineralogy.

- Conduct benthic community analysis.

    - Select upstream reference locations for benthic organism sampling based on grain size, organic carbon, water depth, and water velocity.

    - Collect samples of the benthos from the Study Area and upstream reference areas from the biologically active zone (as defined by SPI results) using box corer or similar sampling device.

    - Collect subsamples of benthic community sediments for analysis of grain size, organic carbon, chloride, and pH. Additional sample volume will be collected for centrifugation and ammonia analysis of the supernatant.

    - Sieve sediments to obtain benthic organisms for offsite taxonomic identification and determination of benthic community structure.

    - Complete statistical comparison of benthic community structure with that of reference sites using standard benthic community indices.

    - Refine assumptions concerning biologically active zone depth based on the results of the SPI.

The activities listed above and described further in Section 3 will be performed in accordance with the Health and Safety Plan presented in Appendix A.

3. Field Activities

3.1 Hydrologic Survey and Sediment Characterization

Hydrographic survey data will be collected by a qualified subcontractor to measure the elevation of the existing sediment surface and provide sediment characterization. The survey will consist of a multi-beam sonar bathymetry, as well as side-scan sonar survey and magnetometer readings. Information obtained during this field activity will assist in establishing the location of samples for subsequent activities.

Bathymetry, metal objects, pipelines, large debris, and sediment types will be mapped as part of the hydrographic survey activities.

3.1.1 Multi-beam Sonar Bathymetry Survey

The entire Study Area as shown in Figure 2 will be surveyed. The survey will include full coverage of the shoreline from Transect 16 downstream to Transect 29 and will extend approximately 300 feet from the shoreline.

The bathymetric and side-scan sonar survey will use sound energy delivered to the sediment bottom to determine water depths and sediment bed elevation. Instrumentation mounted on a ship's hull records the reflected sound through a set of narrow receivers aimed at different angles and ultimately provides bathymetry data and assists with characterizing the geologic makeup of the sediment bottom.

3.1.2 Side-Scan Sonar Survey

The side-scan sonar survey will gather additional sediment bed characteristic information through transducer-produced pulses of sound emitted at an angle to "illuminate" the bottom. Resulting images will be recorded digitally for processing and mapping. This survey will produce a side-scan sonar image of the sediment surface.

3.1.3 Magnetometer Survey

The magnetometer survey will locate metallic objects submerged or buried beneath the sediment surface. The magnetometer detects ferrous-based objects which are submerged or buried beneath the water surface and can determine magnetic anomalies caused by ferrous objects. The collected data will be used to produce maps of metallic features in or on the sediment bed along the shoreline.

3.2 Sediment Probing and Core Collection Activities

Additional sediment cores will be collected for visual observation, field pH measurements, and select cores will be submitted to a laboratory for analysis. Core logs will be completed for each core and made available to the Agencies.

3.2.1 Sediment Probing and Core Collection

Additional sediment cores and probing information will be collected to refine sediment thickness and top of clay elevations within the Study Area. At each core location, water depth and sediment thickness will be measured. Sediment cores will be collected using a Vibracore until refusal according to the Vibracore Sediment Collection Standard Operating Procedure (SOP) in Appendix B of the Phase II Work Plan (ARCADIS 2008b). Core location coordinates will be recorded using Realtime Kinematic Global Positioning System (RTK GPS) equipment. Shoreline positions on each transect will also be surveyed.

Sediment core locations will be selected according to the following guidelines:

- Cores will be collected on Transects 22, 24, and 28 at 25 feet, 50 feet, 75 feet, and 100 feet from the shoreline and then stepwise outward at 25-foot intervals until sediment recovery is less than 2 feet or pH measurements are less than 9.

- Cores will be collected from the transects previously sampled during the Phase II Investigation (Transects 19, 20, 21, 23, 25, 26, 27, and 29) stepwise outward starting at 125 feet from the shoreline until sediment recovery is less than 2 feet or pH measurements are less than 9.

- Cores will be collected from Transects 20 and 26 at locations that were not sampled during the Phase II Investigation. Cores will be collected from Transect 20 at 75 feet from the shoreline and from Transect 26 at 75 feet and 100 feet from the shoreline.

- Transects 16, 17, and 18 will be sampled stepwise moving upstream from Transect 19 and from the shoreline outward in 25-foot intervals to define the extent of pH greater than 9 and sediment thickness greater than or equal to 2 feet. Due to the suspected presence of river bottom pipelines, these cores will be located with consideration of hydrographic survey data and review of historical drawings and information for this area.

3.2.2 Core Field Processing

All collected cores will be described and photographed in the field, and the depth to top of clay recorded. Analytical samples will be collected from each core at 0-0.5 feet, 0.5-1 feet, and subsequent 2-foot intervals until the bottom of the core (established by the native clay layer). Field sediment pH measurements will be taken from 0-0.5 feet, 0.5-1 feet, and subsequent 1-foot intervals according to the Sediment pH Measurements SOP in Appendix B of the Phase II Work Plan (ARCADIS 2008b). The same sampling naming convention will be used as described in Section 5.1 of the Phase II Work Plan (ARCADIS 2008b).

3.2.3 Chemical Analysis

Select sediment cores collected outside of the Phase II Investigation area (see Figure 2) will be submitted for laboratory analysis of the constituents listed in Table 1. The cores will be selected to reflect a spatial density similar to that of Phase II Investigation samples.

Cores will be selected for chemical analysis based on the presence of either elevated (greater than 9) pH or white, light colored material such as that encountered in the Phase II Investigation. Spatial distribution of existing chemical data will also be considered, and cores for chemical analysis will be selected to provide relatively consistent spatial coverage of the Study Area when combined with existing data. Approximately 28 cores are intended to be submitted to TestAmerica Laboratories, Inc. for chemical analysis.

Selected cores will be sectioned from 0-0.5 feet, 0.5-1 feet, and then every 2 feet to the bottom of the core for chemical analysis (note, corresponding pH measurements will be obtained from 1-foot depth intervals as described above). Each sediment core section will be homogenized and placed in glass sample jars according to the Sediment Core Processing SOP in Appendix B of the Phase II Work Plan (ARCADIS 2008b). Cores will then be submitted to the laboratory for analysis. In the event that core sectioning does not produce sufficient volume for both the analyses presented in this IM Work Plan and the volume required for split sample analysis by MDEQ, the analyses listed within this IM Work Plan will take precedence.

Sediment samples will be analyzed according to the constituents and methods listed in Table 1. The analyte list presented in this IM Work Plan was reduced from that used for the Phase II Investigation (ARCADIS 2008b). Based on the results and statistical analysis of the results of the Phase II Investigation (ARCADIS 2009), pesticides and PCBs are excluded from the listed analyses. At the request of USEPA, two constituents that were not included in the Phase II Investigation (ARCADIS 2008b) have been added to the analyte list: 1,2-dichloroethane and vinyl chloride.

3.2.4 Geochemical Characterization of Selected Sediment Samples

Sediment samples will be collected from select cores for geochemical characterization to determine specific mineralogy. Geochemical sediment samples will also be processed following the Sediment Core Processing SOP in Appendix B of the Phase II Work Plan (ARCADIS 2008b). Samples will be obtained from the surface and range of depth intervals.

Cores will be selected for x-ray diffraction analysis (XRD) and x-ray fluorescence (XRF) analysis in locations where the white, light colored material encountered during the Phase II Investigation is present. If a surface “crust” is noted at any location with the white, light colored material, this location will preferentially be selected for submittal of geochemical analysis. Cores for sampling will be selected in the field, in conjunction with Agency oversight. A total of 20 samples will be submitted for XRD and XRF analyses.

3.3 Sediment-Water Interface and Near-Bottom pH Measurements

To evaluate the sediment-water interface, pH measurements will be collected from the surface water near the bottom of the river (i.e. within approximately 6 inches of the sediment surface) and from the porewater present at the interface and in the bioavailable zone. These measurements will be collected using multi-sensor Trident probe technology or equivalent as described in the SOP for the Trident Probe in Appendix B.

3.3.1 Near-Bottom Surface Water pH Measurements

Near-bottom surface water pH measurements will be collected along the southern shoreline of the Site to determine whether or not elevated pH levels detected in the sediments have a measureable influence on surface waters flowing past these areas. Near-bottom pH measurements will be collected at approximately 8 to 10 locations within the Study Area. This evaluation will target locations with elevated pH measured in the top 0.5 feet of sediment. Phase I and Phase II data, as well as new probing pH data collected through this IM Work Plan, will be used to determine the exact sample locations. Sampled locations will be recorded in the field using RTK GPS equipment. The near-bottom surface water pH measurements will be obtained using the surface water sampling sensor on the Trident Probe. Therefore, the measurements will be co-located with the sediment-water interface and bioavailable zone readings.

3.3.2 Sediment-Water Interface pH Measurements

Sediment-water interface pH measurements will also be collected along the southern shoreline of the Site using the Trident Probe. These porewater pH measurements will assist in evaluating the conditions at the sediment-water interface.

Sediment-water interface porewater pH measurements will be collected at the same 8 to 10 locations within the Study Area that near-bottom surface water pH measurements are collected (See Section 3.3.1). Sampled locations will be recorded in the field using RTK GPS equipment.

3.3.3 Sediment Profile Imaging (SPI)

SPI will be used to characterize sediment types and map changes in the sediment floor. SPI measures and analyzes physical, chemical, and biological parameters including:

- Grain size;
- Surface boundary roughness;
- Dredged material or drilling mud thickness;
- Depth of apparent redox potential discontinuity;
- Erosional or depositional features;
- Subsurface methane gas pockets; and
- Observation of benthic organisms.

SPI utilizes a camera that is lowered to the sediment bottom, where it is mechanically driven into the sub-bottom and a digital picture is captured. The images will provide additional information for delineation of the non-native material found previously in these transects during the Phase II Investigation. SPI activities will be conducted according to the SPI QAPP in Appendix B.

SPI digital images will be collected along the southern portion of the Site (Transects 19 through 29) at approximately 30 to 60 locations with three photos at each location, as well as in potential reference locations for benthic community assessment. Those potential reference locations are areas within with sediment cores that were collected during Phase II and are shown on Figure 4. In these areas, SPI locations will be co-located with the existing Phase II sediment core locations to the extent possible and additional locations determined in the field to provide a representation of the degree of variability in sediment type and texture within each area. Data collected during hydrographic survey and core collection activities, in addition to data from past investigations, will be used to guide selection of locations for SPI work. The SPI images will in turn be used to select locations for the Benthic Community Assessment as described below.

3.4 Benthic Community Assessment

One benthic community sample will be collected from each of 8 to 10 Study Area locations and 8 to 10 upstream background locations. Benthic samples will be submitted to a taxonomic laboratory for organism identification and measurement of biomass. Community metrics will be calculated and used in a statistical evaluation to assess the relative condition of the benthos at the Study Area compared to upstream background locations. Based upon the results of this investigation, other data may prove useful or appropriate (e.g., bioassays) to further define causation of biological community differences, if observed. If additional information is needed to develop and implement an appropriate interim measure, it may be collected in the future according to supplemental sampling to be approved by USEPA.

At each location, water quality and flow measurements will be taken, and grain size and total organic carbon (TOC) samples will be collected to document potential habitat and food base conditions. Samples at each location will also be submitted for chloride analysis and centrifugation with ammonia analysis performed on the supernatant. Details of the proposed sampling activities and statistical evaluation are presented below.

3.4.1 Benthic Sample Locations

Sample locations in the Study Area will be selected from areas previously determined to have elevated pH and to contain surface sediments suitable for benthic inhabitation based on SPI grain size and organic carbon data. Reference areas for the benthic community analysis will include locations within areas sampled during Phase II activities that are observed to have similar benthic habitat as the Study Area (Table 2). These may potentially include the areas shown on Figure 4, including:

- Upstream of the Site extending to the mouth of the Ecorse River;
- Shoreline area North of Mud Island;
- East side of Mud Island;
- Southwest side of Mud Island; and
- South of Grassy Island.

In total, 8 to 10 Study Area locations and 8 to 10 reference locations will be sampled for benthic community analysis. In the upstream background, an attempt will be made to collect samples from areas shown on Figure 4 and listed above to represent a range of conditions. The specific areas shown in Figure 4 and locations within those areas to be selected for use as reference locations for the benthic community assessment will be selected based on consideration of habitat characteristics including water depth, sediment grain size, relative flow velocity, and visual characteristics as observed through the SPI images to be collected in these areas (see above). All sample locations in reference areas for benthic community assessment will be selected in conjunction with Agency oversight. However, areas with dissimilar habitat to the Study Area based on field observations (water depth, water velocity, grain size, organic carbon) may not be sampled.

3.4.2 Benthic Community Sampling

Benthic samples will be collected from a boat using a box corer, Ponar sampler, or other appropriate grab sampler or other suitable device based on Site conditions. A range of depth of surface sediments has been used in benthic community studies. National monitoring programs often use the upper 2 centimeters of sediments as representative of the biologically active zone (see National Oceanic and Atmospheric

Administration [NOAA] 1995 and USEPA 2003). The benthic community assessment was originally proposed to focused on characterizing benthos in the biologically active zone; however, USEPA (Thomas 2009) requested sampling of the top 6 inches of surface sediments for consistency with the depth intervals utilized for core sampling--this greater depth interval has been accommodated in this IM Work Plan. A sampling depth of 6 inches will be utilized unless the SPI imagery provides a basis for a shallower depth interval, in which case this would be discussed and approved by USEPA before a shallower interval would be used. A depth of 6 inches will be sufficient to capture benthic organisms in studies provided by USEPA for consideration in design of this IM Work Plan (e.g., Cibrowski 2003; USEPA 2000).

At each location, water depth, water quality, and flow readings will be taken, and one benthic community, one grain size sample, one TOC sample, and one chloride sample will be collected. A volume of bulk sediment will also be collected for centrifugation and ammonia analysis on the resulting supernatant. One duplicate grain size, TOC, chloride, and ammonia sample will each be collected from the Study Area and upstream background. Sampling will be conducted as follows and as listed in the benthic sampling SOPs (Appendix B).

- The boat will be anchored for stability, and water depth will be measured using an incremented survey rod or digital depth finder.
- Water quality will be measured using a multi-parameter probe within 1 meter of the water column top and bottom. Water temperature, pH, conductivity, turbidity, and dissolved oxygen will be measured.
- Flow will be measured using an electromagnetic flow meter within 1 meter of the water column top and bottom.
- One benthic community sample will be collected from each location.
- One grain size, one TOC, one chloride, and one ammonia (from supernatant resulting from sediment centrifugation) sample will be collected from additional sediment grabs that are homogenized. Laboratory methods for these analyses are listed in Table 1.

3.4.3 Benthic Sample Processing

Benthic community samples will be sieved in the field using a U.S. standard No. 30 (0.6 millimeter) sieve to remove fine sediments and then preserved in 1-liter plastic jars in 70% isopropyl alcohol. Benthic samples will be sent to Normandeau Associates Inc., in Stowe, Pennsylvania for identification of organisms to the lowest practical taxonomic unit (typically genus or species) and measurement of wet weight biomass. Laboratory QA/QC procedures (sorting, identification, subsampling) are presented in the QAPP.

Grain size, TOC, chloride, and ammonia samples will be formed from homogenized sediments. Grain size samples will be placed in 1-gallon sealable plastic bags, and TOC, chloride, and sediment for centrifugation for ammonia analysis samples will be placed in 250-milliliter jars on ice and sent to TestAmerica Laboratories, Inc. Observations of sediment odor or sheen, if present, will be recorded in the field notes during homogenization. Laboratory QA/QC procedures are presented in the QAPP (Environmental Science & Engineering, Inc. 1996; ARCADIS 2008a).

3.4.4 Benthic Community Analysis

The benthic data will be tabulated and standard community metrics will be calculated. The metrics will be used in a statistical evaluation to determine if differences between the Study Area and upstream background populations are statistically significant (α=0.05). The metrics selected may include measures of benthic abundance, richness, composition, tolerance, and/or life history adaptations as recommended by USEPA Rapid Bioassessment Protocols (USEPA 1999).

Both univariate and multivariate statistical analysis will be conducted to compare upstream conditions to Study Area conditions. Univariate evaluations will be performed on a metric-by-metric basis to determine if the central tendency (e.g., mean) and upper tails of the distributions are similar. In addition, evaluations will be conducted to determine if the habitat conditions such as grain size distribution (e.g., percent fines), TOC, water depth, and flow velocity are similar among upstream and Study Area sampling locations. Differences in one or more of these factors may partly explain the variance in benthic community metrics. The following exploratory data analysis and statistical analysis methods will be generated to conduct these evaluations.

Exploratory Data Analysis:

- Data visualization – box-and-whisker plots, probability plots, and post plots (maps).
- Correlation analysis – bivariate scatter plots with 95% prediction intervals, Spearman rank correlation matrix.
- Goodness-of-fit (GOF) tests for normality – Shapiro-Wilk test (α=0.05).

- Outlier tests – Rosner, Dixon, Walsh, or interquartile range test, depending on sample size and GOF results for normality or lognormality.

- Homogeneity of variance test – ratio of standard deviations, *F*-test, or Levine's test depending on GOF results for normality or lognormaility.

Statistical Tests:

- One-way Analysis of Variance (ANOVA) – parametric ANOVA if data are approximately normal (or can be transformed to approximately normal), or Kruskal-Wallis test. Multiple contrasts will be evaluated to determine if overall differences in populations can be attributed to specific locations. For individual benthic community metrics, a single result is obtained for each location. Therefore, hypothesis testing reduces to the standard two-sample t-test for normal distributions or the Wilcoxon Rank Sum test for nonnormal distributions.

- Quantile test – to compare upper tails of distributions for Upstream and Study Area locations.

Multivariate statistical analysis will also be performed to investigate the association between the benthic community indices and habitat conditions. Data reduction techniques will be explored using indices of dissimilarity and clustering, including Bray-Curtis coefficients and principal component analysis.

4. Remedial Alternatives Evaluation and Selection

Based on evaluation of the data obtained following implementation of this IM Work Plan, potential remedial alternatives will be identified and evaluated as potential interim measures with consideration of the following (based on USEPA 2005):

- Protectiveness of human health and the environment;
- Long-term effectiveness and permanence;
- Short-term effectiveness;
- Implementability;
- Potential impacts to the public;
- Cost; and
- Agency acceptance.

Each alternative will be described and evaluated with the consideration that the selected alternative would be applied as an interim measure that would be expected to comprise part of the overall final corrective action for the Site. At the conclusion of the evaluation, an alternative will be recommended in consultation with USEPA and MDEQ, and an Interim Measure Design Work Plan for the alternative approved by USEPA under the AOC will be prepared. Potential alternatives to be evaluated individually and in combination will include:

- No Action;
- Monitored Natural Recovery;
- Sediment Capping;
- Sediment Removal; and
- In-situ Treatment.

For removal, capping, and in-situ treatment alternatives, more than one technology may be identified and evaluated. Removal evaluations will consider potential residual conditions that may remain post-removal. All capping, treatment, and removal scenarios will specifically consider recontamination potential. Consideration of any in-place management alternatives such as capping will specifically consider long-term stability.

The description of each specific alternative will include a proposed spatial extent (i.e., boundaries of application) and basis for that extent. The basis for the spatial extent will consider not only sediment pH values (of which USEPA and MDEQ have expressed specific concern), but also concentrations of other constituents.

The identification and evaluation of alternatives based on the results of the supplemental investigation work to be completed per Section 3 of this IM Work Plan will be included in the IM Report to be submitted as described in Section 5.

5. Reporting

5.1 IM Report

An IM Report will be prepared and submitted to USEPA for review and comment.

The IM Report will include:

- Field notes and logs;
- Hydrographic survey images and maps;
- Summary of visual core sample observations;
- Photographs of sediment samples;
- Figures showing all sampling locations;
- Summary tables of analytical and pH results;
- pH isopleths maps for approximately 1 foot depth increments based on sediment core data;
- SPI photographic images;
- Benthic community assessment results;
- Evaluation of remedial alternatives; and
- Selection of proposed remedial alternative.

5.2 Progress Report

Progress reports documenting the status of the interim measure will be submitted to USEPA on a monthly basis. These status updates will be contained within the Site wide monthly progress report that is currently being submitted that documents the progress of overall RCRA facility activities.

6. Public Participation

This IM Work Plan and all other project documents that have been approved in writing by USEPA and are determined to be final will be placed in the project public repository which is the Bacon Memorial District Library located at 45 Vinewood St., in Wyandotte, Michigan.

7. Project Schedule

7.1 Work Sequence for Investigative Activities

The proposed schedule of activities is presented in Figure 3. The following work sequence is proposed to facilitate the informed selection of sampling locations for each field activity (i.e., the information obtained in Step 1 will assist in locating samples for Steps 2 and 3). The scheduled USEPA data share meetings (Figure 3) are a critical component of this IM Work Plan, and it is necessary that they occur in a timely fashion to facilitate the next step of field work. ARCADIS proposes that the first two meetings be held at the ARCADIS office located in Brighton, Michigan or at BASF facilities to facilitate MDEQ's in-person attendance; USEPA may participate via conference call if travel is not an option. The third data share meeting will take place in Wyandotte, Michigan, and it is expected that USEPA would participate in-person for the selection of benthic community analysis locations. The main agenda item for each data share meeting will be the selection of sample locations for the next phase of field work.

<u>Step 1 – Hydrographic Survey</u>

- Complete hydrographic survey (with bathymetry, side-scan sonar, and magnetometer).

<u>Step 2 – Probing and Core Sampling</u>

- Complete probing of sediment thickness, top of clay elevation, and measurement of pH profiles.

- Complete core sampling (geochemical and analytical chemistry) for subset of cores collected during probing.

<u>Step 3 – Sediment-Water Interface Evaluation</u>

- Complete SPI.

- Collect near-bottom and sediment-water interface pH measurements.

Step 4 – Benthic Community Assessment

- Collect samples of the benthos from the Study Area and upstream reference areas from the biologically active zone (as defined by SPI results).
- Collect subsamples of benthic community sediments for analysis of grain size, TOC, chloride, ammonia (via analysis of supernatant from centrifugation), and pH.
- Complete statistical comparison of benthic community structure with that of reference sites using standard benthic community indices.

7.2 Proposed Overall Schedule Including Alternatives Analysis

The proposed overall schedule of activities is outlined in Figure 3. The principal elements of this IM Work Plan are the field sampling activities necessary to fill key data gaps; the alternatives analysis; and the development of appropriate interim measures in consultation with the Agencies. The schedule presented is dependent on Agency review cycles. Ongoing frequent correspondence between the Agencies and BASF during these review cycles will facilitate maintaining the proposed schedule.

Additional separate IM subplans may be developed concurrently with the implementation of this IM Work Plan and will be dependent on the results of the implementation of this IM Work Plan. When identified, the schedule will be amended in consultation with the Agencies to reflect the development of the additional plans.

8. References

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USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. Office of Environmental Information. EPA/240/B-06/001. February.

USEPA. 2009a. Letter from Juan Thomas to Michael Gerdenich, BASF. Subject: BASF North Works – Sediment pH Levels Alongside BASF North Works, Trenton Channel. April 24, 2009.

USEPA. 2009b. Letter from Juan Thomas to Michael Gerdenich, BASF. Subject: BASF North Works – June 2, 2009 Sediment Characterization/Remedial Evaluation Interim Measures Work Plan (IM Work Plan). July 17, 2009.

ARCADIS

Tables

Table 1 -- Supplemental Sampling Analyte Decision Matrix

Analyte	No Detections	Few Detections - Mostly Upstream	Frequency of Non-detect >> Detect	No BSL Exceedance	No ESL Exceedance	% Detects Along Site - Total	% Detects Along Site - South	% Detects Upstream	To be analyzed?	Notes
Inorganics 6020 [1] (mg/kg)										
Aluminum						100%	100%	100%	Y	
Antimony				x		100%	100%	100%	Y	
Arsenic						100%	100%	100%	Y	
Barium						100%	100%	100%	Y	
Beryllium						100%	100%	100%	Y	
Cadmium				x		100%	100%	100%	Y	
Chromium				x		100%	100%	100%	Y	
Cobalt				x	x	100%	100%	100%	Y	
Copper				x		100%	100%	100%	Y	
Lead						100%	100%	100%	Y	
Nickel				x		100%	100%	100%	Y	
Selenium						100%	100%	100%	Y	
Silver						100%	100%	97%	Y	
Thallium						100%	100%	100%	Y	
Vanadium				x		100%	100%	100%	Y	
Zinc				x		100%	100%	100%	Y	
Inorganics 7470/7471 [1] (mg/kg)										
Mercury				x		100%	100%	100%	Y	
Inorganics 9010 [1] (mg/kg)										
Cyanide						85%	85%	99%	Y	
Volatile Organic Compounds 8260 [1] (ug/kg)	14 days to analyze									
1,2,4-Trichlorobenzene	x					0%	0%	0%	Y	Non-detect for all datasets
1,2-Dichlorobenzene		x				1.7%	1.7%	7.2%	Y	Low detection frequency Along Site
1,2-Dichloropropane / propylene dichloride (PDC)			x			3.4%	3.4%	0%	Y	Low detection frequency Along Site
Benzene						52%	50%	74%	Y	
Chlorobenzene			x			16%	16%	0%	Y	
Ethylbenzene			x			37%	35%	46.4%	Y	
Isopropylbenzene			x			48%	46%	66.7%	Y	Low detection frequency Along Site
Methyl Ethyl Ketone / 2-Butanone			x			0.84%	0.86%	0%	Y	Low detection frequency Along Site
sec-Butylbenzene			x			20%	20%	16%	Y	
Styrene		x	x		x	6.7%	6.0%	14%	Y	Low detection frequency Along Site
Toluene					x	81%	80%	91%	Y	Detected concentrations do not exceed ESL
Xylenes (ortho, meta, and para)					x	61%	60%	87%	Y	Detected concentrations do not exceed ESL
1,2-Dichloroethane									Y	Not analyzed for in Phase II
Vinyl Chloride									Y	Not analyzed for in Phase II

Table 1 -- Supplemental Sampling Analyte Decision Matrix

Analyte	No Detections	Few Detections - Mostly Upstream	Frequency of Non-detect >> Detect	No BSL Exceedance	No ESL Exceedance	% Detects Along Site - Total	% Detects Along Site - South	% Detects Upstream	To be analyzed?	Notes
Semivolatile Organic Compounds 8270 [2] (ug/kg)										
2,4,6-Trichlorophenol (TCP)		x				0%	0%	1.4%	Y	Non-detect for Along Site samples
2,4-Dimethylphenol			x			18%	18%	5.8%	Y	Low detection frequency Along Site
2,4-Dinitrotoluene	x					0%	0%	0%	Y	Non-detect for all datasets
2-Chlorophenol	x					0%	0%	1.4%	Y	Non-detect for all datasets
2-Methylnaphthalene				x		98%	98%	94%	Y	Upstream values higher than Along Site
3 & 4 Methylphenol						88%	88%	78%	Y	
4-Chloro-3-methylphenol	x					0%	0%	0%	Y	Non-detect for all datasets
Benzyl Alcohol	x					0%	0%	0%	Y	Non-detect for all datasets
bis(2-Chloroisopropyl)ether (BCE)		x				4.6%	4.7%	0%	Y	Low detection frequency Along Site
bis(2-Ethylhexyl)phthalate						62%	61%	68%	Y	
Di-n-octyl phthalate			x		x	11%	8.7%	22%	Y	Low detection frequency Along Site
N-Nitrosos-di-n-propylamine	x					0%	0%	0%	Y	Non-detect for all datasets
Pentachlorophenol	x					0%	0%	0%	Y	Non-detect for all datasets
Phenol						65%	66%	10%	Y	
Polynuclear Aromatic Hydrocarbons 8270 [2] (ug/kg)										
Acenaphthylene						92%	92%	94%	Y	
Anthracene						98%	98%	99%	Y	
Benzo(a)anthracene						99%	99%	99%	Y	
Benzo(a)pyrene						98%	98%	99%	Y	
Benzo(b)fluoranthene						98%	98%	99%	Y	
Benzo(g,h,i)perylene						98%	98%	99%	Y	
Benzo(k)fluoranthene						9.2%	9.4%	19%	Y	
Chrysene						99%	99%	99%	Y	
Dibenzofuran						93%	93%	86%	Y	
Fluoranthene						99%	99%	99%	Y	
Fluorene						98%	98%	91%	Y	
Indene						58%	58%	64%	Y	
Indeno(1,2,3-cd)pyrene						98%	98%	99%	Y	
Naphthalene						98%	98%	96%	Y	
Phenanthrene						100%	100%	100%	Y	
Pyrene						99%	99%	99%	Y	
PCBs 8082 [1] (ug/kg)										
Aroclor 1248				x		58%	57%	77%	N	Upstream values higher than Along Site
Aroclor 1254				x		67%	66%	78%	N	Upstream values higher than Along Site
Aroclor 1260				x		70%	69%	81%	N	Upstream values higher than Along Site
Pesticides 8081 [1] (ug/kg)										
4,4'-DDE				x		67%	66%	71%	N	Upstream values higher than Along Site

BASF Corporation - North Works
Wyandotte, Michigan
Sediment Characterization/Remedial Evaluation Interim Measures Work Plan

Table 1 -- Supplemental Sampling Analyte Decision Matrix

Analyte	No Detections	Few Detections - Mostly Upstream	Frequency of Non-detect >> Detect	No BSL Exceedance	No ESL Exceedance	% Detects Along Site - Total	% Detects Along Site - South	% Detects Upstream	To be analyzed?	Notes
Other (mg/kg)										
pH SM 9045 (field test)[3]						-	-	-	Y	
Total Sulfides (9034 [1])						96%	96%	100%	Y	
Total Organic Carbon (Lloyd Kahn)						-	-	-	Y	
Chloride (300.0/9056A [5])									Y	Not analyzed for in Phase II
Ammonia (350.1 [6])									Y	Not analyzed for in Phase II
Grain Size						-	-	-	Y	

Abbreviations

ug/kg - micrograms per kilogram
mg/kg - milligrams per kilogram
BSL - Biological Screening Level
ESL - Ecological Screening Level

Notes:

1) USEPA. Office of Solid Waste and Emergency Response. *Test Methods for Evaluating Solid Waste SW-846 3rd ed. Washington, D.C. 1996.*
2) APHA. Standard Methods for the Examination of Water and Wastewater. Washington, DC 1998.
3) Per USEPA-approved methods in Phase II Sediment Investigation Work Plan.
4) Detections and exceedances are based on data summarized in the *Phase II Sediment Investigation: Data Summary Report* (ARCADIS 2009).
5) Chloride analysis to be run on sediment samples collected at Benthic Community sample locations.
6) Ammonia analysis to be run on supernatant of centrifuged sediment samples collected at Benthic Community sample locations.

BASF Corporation - North Works
Wyandotte, Michigan
Sediment Characterization/Remedial Evaluation Interim Measures Work Plan

Table 2 -- Water Depth, TOC, Grain Size Data from Phase II Sediment Samples within Reference Areas for Benthic Community Survey

Location	Number of Locations	Distance from Shore (ft) Low	Distance from Shore (ft) High	Water Depth (ft) Low	Water Depth (ft) High	Total Organic Carbon[1] Sample Interval (ft)	Organic Carbon (%) Low	Organic Carbon (%) High	Grain Size[1] Shallowest Sample Interval (ft)	Dominant Sediment Type	Dominant Sediment Group
Along Site South											
T19	4	25, 50, 75, 100		22.0	26.2	0-0.5	5.94	7.38	0-1	Fine Sand	Fine Sand
T20	3	25, 50, 100		21.7	28.0	0-0.5	4.20	9.30	0-1	Fine Sand	Fine Sand
T21	4	25, 50, 75, 100		19.1	28.0	0-0.5	5.32	28.8	1-3	Fine Sand	F.Sand/Clay&Silt
T23	4	25, 50, 75, 100		19.1	25.0	0-0.5	6.44	8.30	0-2	Fine Sand	Fine Sand
T25	4	25, 50, 75, 100		14.2	26.5	0-0.5	5.90	7.65	0-1	Silt	Clay & Silt
T26	2	25, 50		12.3	18.3	0-0.5	7.11	7.68	0.5-2	Fine Sand	Clay & Silt
T27	4	25, 50, 75, 100		8.2	19.0	0-0.5	6.00	8.83	0-1.6	Clay	Clay & Silt
T29	4	25, 50, 75, 100		8.8	19.0	0-0.5	6.02	10.0	0-1	Silt	Clay & Silt
Along Site North											
T01	1	50		15.1		0-0.5	4.85		1-3	Fine Sand	Fine Sand
Upstream											
U01	1	--		2.5		0-0.5	9.72		0-1.1	Silt	Clay & Silt
U02	1	--		13.0		0-0.5	9.27		1-3	Fine Sand	Clay & Silt
U04	1	--		4.2		0-0.5	8.13		3-5	Silt	Clay & Silt
U05	1	--		4.0		0-0.5	6.29 J		1-3	Silt	Clay & Silt
U07	1	--		5.5		0-0.5	10.9		1-3	Silt	Clay & Silt
U08	1	--		4.0		0-0.5	10.9		3-5	Silt	Clay & Silt
U09	1	--		4.5		0-0.5	11.3		1-3	Silt	Clay & Silt
U10	1	--		7.0		0-0.5	8.42		1-3.4	Silt	Clay & Silt
U11	1	--		16.8		0-0.5	7.66		1-3.2	Silt	Clay & Silt
U13	1	--		9.8		0-0.5	1.36		0-0.5	Fine Sand	Fine Sand
U14	1	--		13.0		0-0.5	5.32		0-1	Fine Sand	M.C.Sand&Gravel
U15	1	--		9.3		0-0.5	5.24		0-1	Silt	Clay & Silt
U19	1	--		3.6		0-0.5	9.15		1-3	Silt	Clay & Silt
U20	1	--		5.4		0-0.5	8.52		1-3	Silt	Clay & Silt
U21	1	--		4.0		0-0.5	9.91		1-3	Silt	Clay & Silt
U22	1	--		8.7		0-0.5	11.4		--	--	--
Grassy Island											
G01	1	--		2.8		0-0.5	4.66		1-2.4	Clay	Clay & Silt
G02	1	--		3.6		0-0.5	6.33		1-3.2	Clay	Clay & Silt
G03	1	--		6.0		0-0.5	4.87		1-3.3	Silt	Clay & Silt
G04	1	--		5.3		0-0.5	5.34		0-1	Silt	Clay & Silt
G05	1	--		5.0		0-0.5	2.59		0-2	Silt	Clay & Silt
G-06	1	--		5.4		0-0.5	5.06		1-3	Silt	Clay & Silt

Notes:

1) Data from *Phase II Sediment Investigation: Data Summary Report* (ARCADIS 2009).

2) The Ecorse River (and mouth) was not selected as a potential background area for benthic sampling since it is unlikely to be representative of conditions in the Detroit River and may naturally have a different benthic community.

3) Locations in the vicinity of Grassy Island are not included as potential background areas due to close proximity to the site. However, benthic community sampling will be performed in this area to provide additional data on communities in the Detroit River.

4) The Libra Marina high pH area was not selected as a potential background area since it is unlikely to be representative of upstream conditions in the Detroit River.

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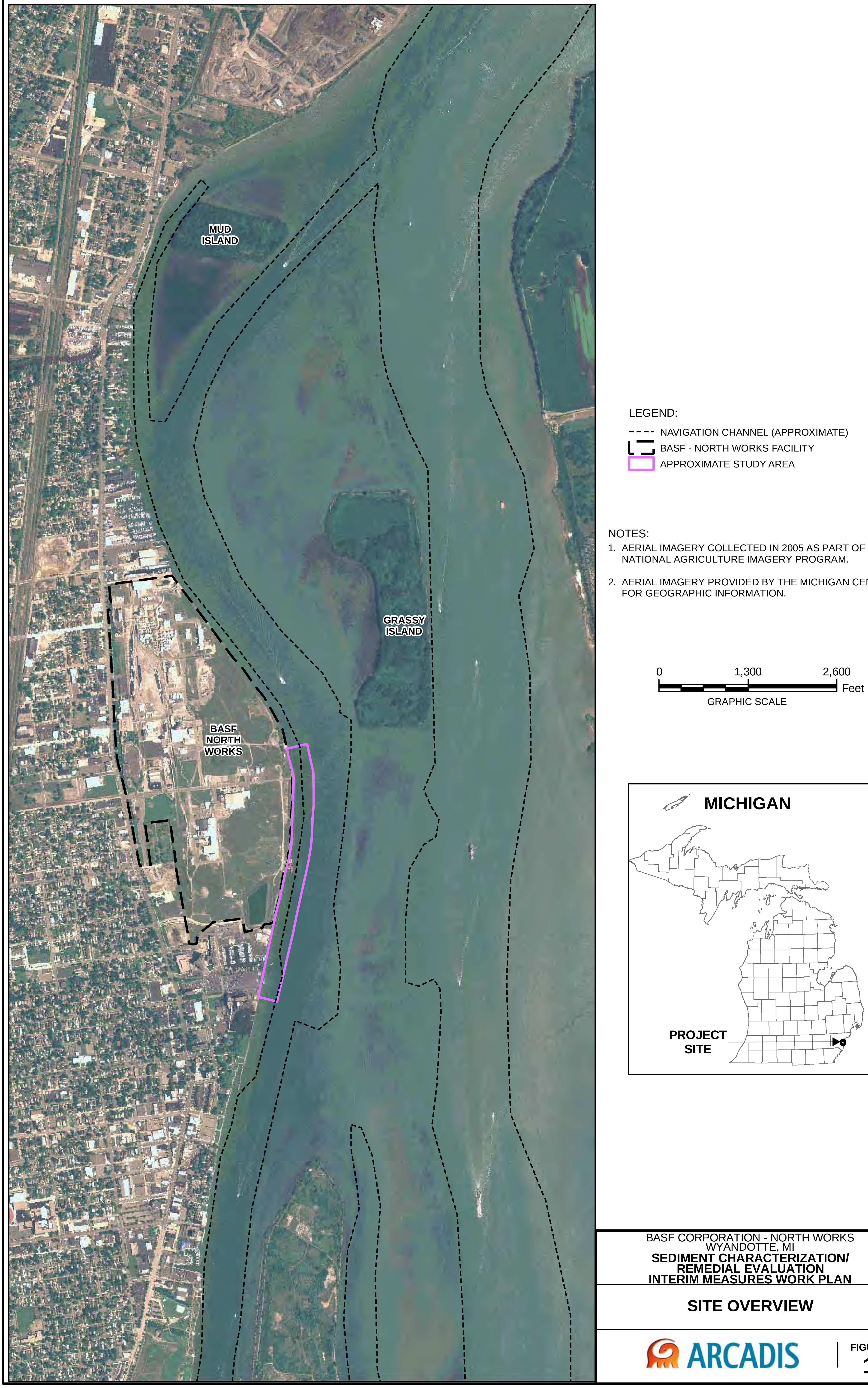
Figures

SYR- AIT JCR KEW
BASF North Works (42929.00015)
O:\BASF_DetroitRiver_MI\NorthWorks\SupplementalSedimentCharacterizationWP\mxd\Site Overview_v2.mxd - 7/31/2009 @ 11:07:48 AM



NOTES:
1. AERIAL IMAGERY COLLECTED IN 2005 AS PART OF THE NATIONAL AGRICULTURE IMAGERY PROGRAM.
2. AERIAL IMAGERY PROVIDED BY THE MICHIGAN CENTER FOR GEOGRAPHIC INFORMATION.

0 1,300 2,600 Feet
GRAPHIC SCALE

BASF CORPORATION - NORTH WORKS
WYANDOTTE, MI
SEDIMENT CHARACTERIZATION/ REMEDIAL EVALUATION INTERIM MEASURES WORK PLAN

SITE OVERVIEW

ARCADIS

FIGURE
1

CITY:SYR DEPT: AIT DB: JCR
BASF North Works (42929.0005.00010)
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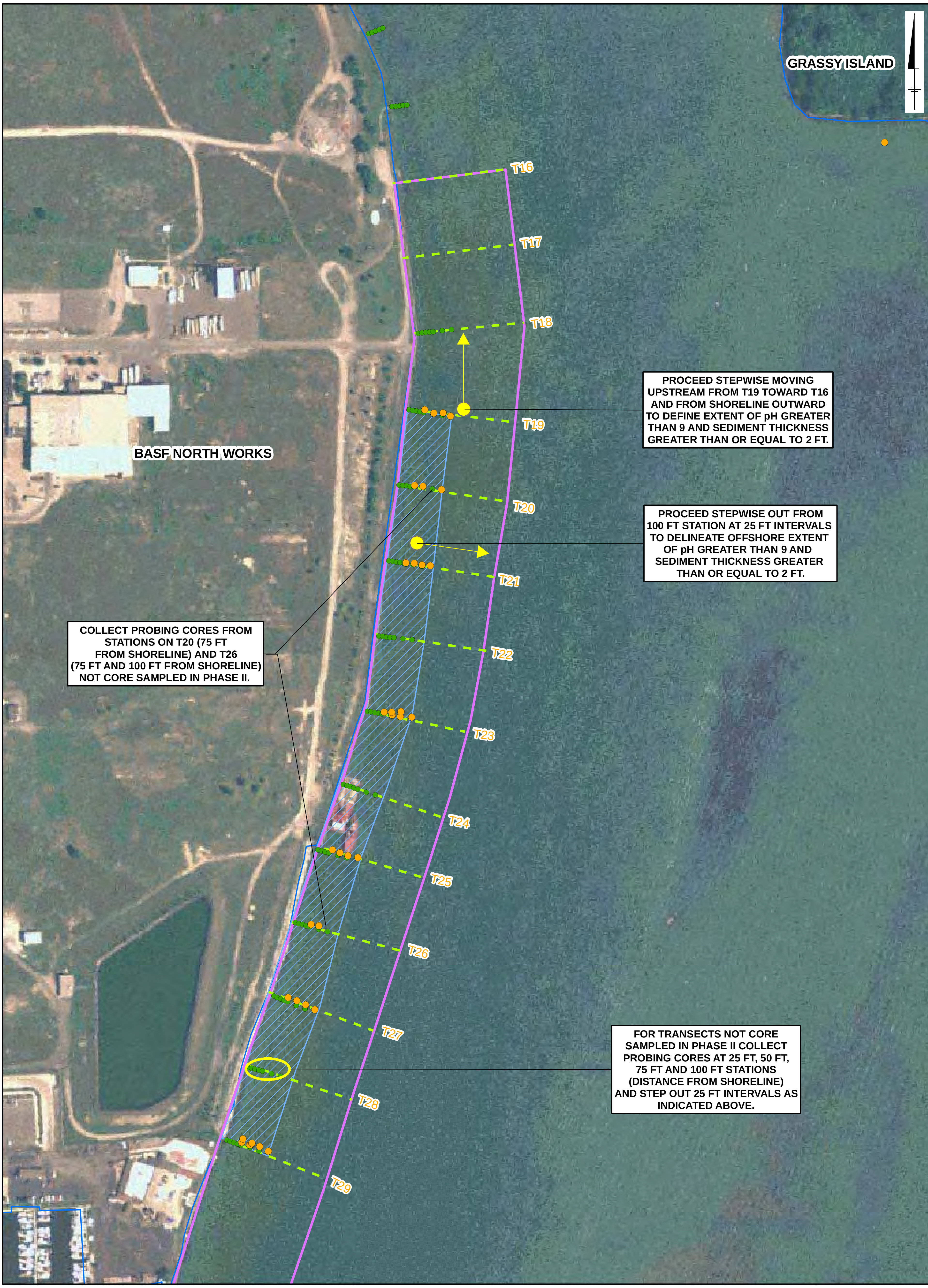


LEGEND:

- PHASE II SEDIMENT CORE LOCATION (LOCATION FOR T20-25 IS APPROXIMATE)
- PHASE I PROBE LOCATION
- PROPOSED CORE COLLECTION TRANSECT
- SHORELINE (APPROXIMATE)
- APPROXIMATE STUDY AREA
- PHASE II SEDIMENT INVESTIGATION AREA (APPROXIMATE)

NOTE:

1. 2005 AERIAL IMAGERY PROVIDED BY THE MICHIGAN CENTER FOR GEOGRAPHIC INFORMATION.

0 250 500 Feet

GRAPHIC SCALE

BASF CORPORATION - NORTH WORKS
WYANDOTTE, MI

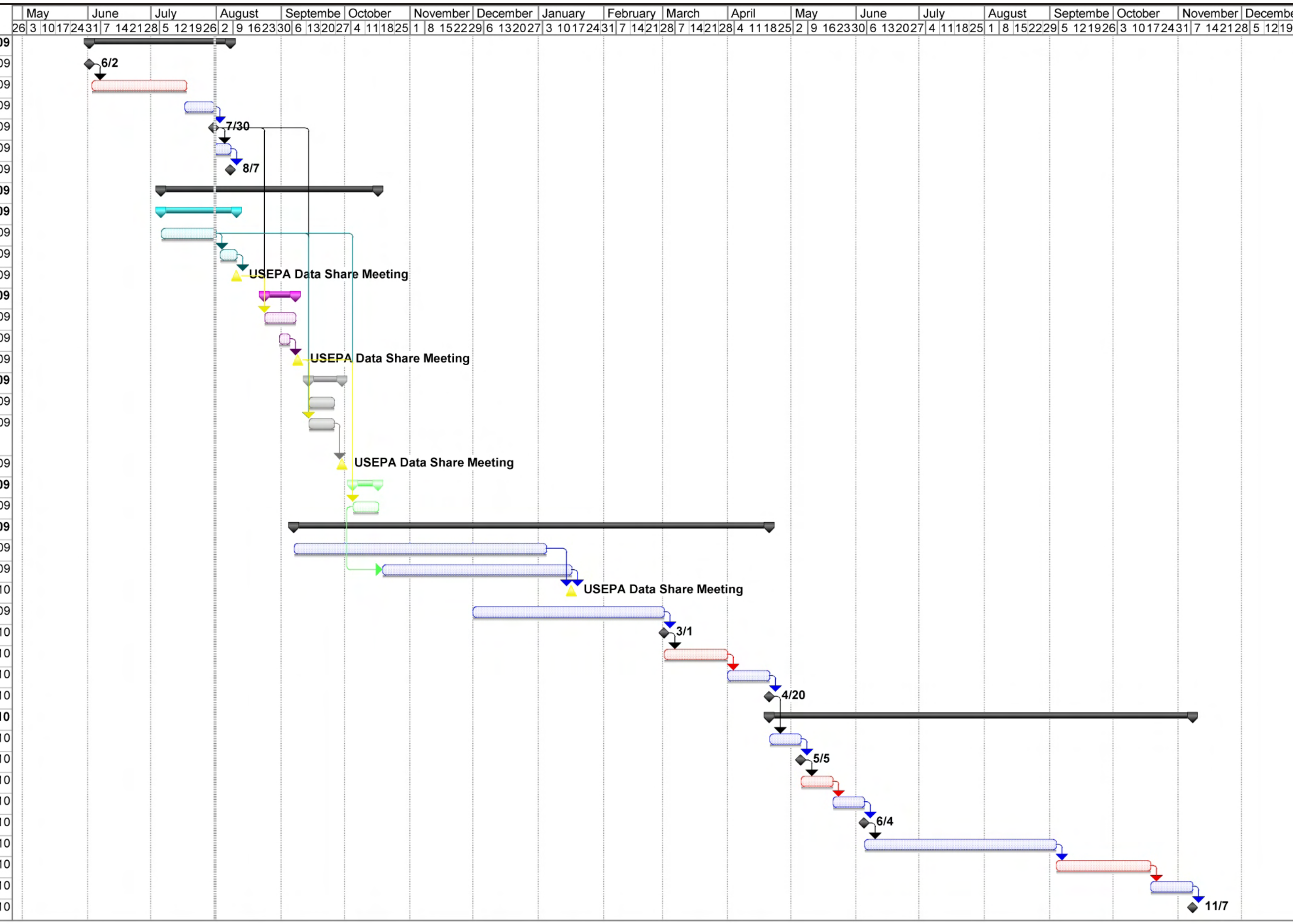
SEDIMENT CHARACTERIZATION/ REMEDIAL EVALUATION INTERIM MEASURES WORK PLAN

SEDIMENT STUDY AREA

ARCADIS

FIGURE
2

ID	Task Name	Duration	Start
1	**IM Work Plan**	**67 days**	**Tue 6/2/09**
2	Submit IM Work Plan for Agency Review	0 days	Tue 6/2/09
3	USEPA Review of IM Work Plan	45 days	Wed 6/3/09
4	Revise IM Work Plan	14 days	Fri 7/17/09
5	Submit Final IM Work Plan	0 days	Thu 7/30/09
6	USEPA Review of Revised IM Work Plan	8 days	Fri 7/31/09
7	USEPA IM Work Plan Approval	0 days	Fri 8/7/09
8	**Field Activities**	**103 days**	**Mon 7/6/09**
9	**Step 1**	**36 days**	**Mon 7/6/09**
10	Bathymetry Survey	26 days	Mon 7/6/09
11	Review Survey Data and Layout Core Plan	8 days	Mon 8/3/09
12	USEPA Data Share - Discuss Step 2 Location Layout	1 day	Tue 8/11/09
13	**Step 2**	**15 days**	**Mon 8/24/09**
14	Sediment Probing and Core Collection	15 days	Mon 8/24/09
15	Review Probing Data and Layout Step 3 Locations	5 days	Mon 8/31/09
16	USEPA Data Share - Discuss Step 3 Location Layout	1 day	Wed 9/9/09
17	**Step 3**	**16 days**	**Mon 9/14/09**
18	Sediment Profiling Imaging (SPI)	12 days	Mon 9/14/09
19	Sediment-Water Interface and Near Bottom pH Measurements	12 days	Mon 9/14/09
20	USEPA Data Share - Discuss Step 4 Location Layout	0 days	Wed 9/30/09
21	**Step 4**	**12 days**	**Mon 10/5/09**
22	Benthic Community Assessment	12 days	Mon 10/5/09
23	**Prepare IM Report**	**226 days**	**Mon 9/7/09**
24	Laboratory Analysis and Data Validation/Management	120 days	Mon 9/7/09
25	Laboratory - Benthic Community Analysis	90 days	Mon 10/19/09
26	USEPA Data Share	0 days	Sat 1/16/10
27	Prepare Draft IM Report	91 days	Tue 12/1/09
28	Submit Draft IM Report	0 days	Mon 3/1/10
29	USEPA Review of Draft IM Report	30 days	Tue 3/2/10
30	Revisions to IM Report	20 days	Thu 4/1/10
31	Submit IM Report for USEPA Approval	0 days	Tue 4/20/10
32	**IM Design Program**	**200 days**	**Wed 4/21/10**
33	Prepare Draft IM Design Work Plan	15 days	Wed 4/21/10
34	Submit Draft IM Design Work Plan	0 days	Wed 5/5/10
35	USEPA Review	15 days	Thu 5/6/10
36	Revisions to IM Design Work Plan	15 days	Fri 5/21/10
37	Submit IM Design Work Plan for USEPA Approval	0 days	Fri 6/4/10
38	Prepare Draft IM Design	90 days	Sat 6/5/10
39	USEPA Review	45 days	Sat 9/4/10
40	Revisions to Draft IM Design	20 days	Tue 10/19/10
41	Submit IM Design for USEPA Approval	0 days	Sun 11/7/10



Project: BASF - IMWP Sediments_Sche
Date: Fri 7/31/09

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

BASF CORPORATION - NORTH WORKS
WYANDOTTE, MICHIGAN

SEDIMENT CHARACTERIZATION/REMEDIAL EVALUATION INTERIM MEASURES WORK PLAN

PROPOSED ACTIVITIES SCHEDULE

ARCADIS

FIGURE
3

06/01/09 SYRACUSE, NY DIV: ENV/CAD K. SARTORI
B0042929/0005/00012/CDR/42929F01.CDR

CITY:SYR DEPT: AIT DB: JCR KEW JCR
BASF North Works (42929.0005.00010)
O:\BASF_DetroitRiver_MI\NorthWorks\SupplementalSedimentCharacterizationWP\mxd\ProposedBenthicSamplingAreas_v2.mxd - 7/31/2009 @ 11:11:54 AM

LEGEND:

- PHASE II SEDIMENT CORE LOCATION
- BASF NORTH WORKS PROPERTY
- REFERENCE AREA (SPECIFIC LOCATIONS FIELD DETERMINED BASED ON PRIOR DATA AND SPI IMAGERY IN CONJUNCTION WITH AGENCY OVERSIGHT)

0 700 1,400 Feet
GRAPHIC SCALE

NOTE:

1. 2005 AERIAL IMAGERY PROVIDED BY THE MICHIGAN CENTER FOR GEOGRAPHIC INFORMATION.

BASF CORPORATION - NORTH WORKS
WYANDOTTE, MI
SEDIMENT CHARACTERIZATION/ REMEDIAL EVALUATION INTERIM MEASURES WORK PLAN

POTENTIAL BENTHIC COMMUNITY SAMPLING REFERENCE LOCATIONS

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FIGURE
4

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Appendix A

Health and Safety Plan

(Located on attached CD)

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Appendix B-1

Trident Probe Standard Operating Procedure

Trident Probe Standard Operating Procedure (SOP)

Prepared by:
Coastal Monitoring Associates
May 8, 2009

Standard Operating Procedure for the Trident Probe

1.0 Scope and Application

The application of this sampling procedure is for the collection of surface and subsurface sensor readings and water samples using the Trident Probe.

2.0 Summary of Procedure

The Trident probe is a direct-push, integrated temperature sensor, conductivity sensor, and porewater sampler developed to screen sites for areas where groundwater may be discharging to a surface water body (Chadwick et al., 2003). Differences in observed conductivity and temperature indicate areas where groundwater discharge is occurring. The integral porewater sampler can be used to rapidly confirm the presence of groundwater conductivity contrast or to map the distribution of other chemical constituents.

The temperature sensor consists of a ruggedized digital oceanographic thermometer embedded near the tip of a 90 cm long stainless-steel probe. The conductivity probe utilizes a small diameter, stainless steel, AC-excitation 3-electrode sensor, installed at the tip of the same 90 cm probe that houses the temperature sensor. The conductivity signal varies primarily as a function of changes in salinity or TDS, and secondarily as a function of clay content and porosity. A secondary screen and purge tube can be installed over the sensor to provide direct porewater readings and eliminate the effects of the sediment matrix. A reference conductivity and temperature sensor is mounted on the instrument frame to provide a direct comparison of the overlying surface water conditions with the interstitial water conditions (contrast). For the temperature sensor, areas of groundwater seepage may appear either as warm or cold contrast to the surface water depending on the seasonal and site characteristics. For the conductivity sensor, areas of likely groundwater seepage in coastal areas are generally associated with low conductivity as a result of low salinity, while in river systems, groundwater discharge is often associated with higher TDS due to groundwater age and interaction with subsurface soils.

The water-sampling probe allows interstitial waters to be extracted from the sediment at selected depths up to about 90 cm below the sediment water interface. Porewater is collected by syringe or low-flow pump extraction through a small-diameter, Teflon-coated, stainless steel probe. The probes consist of a length of 95 mm diameter stainless steel tubing fitted with a solid, removable point. On the side of the tube near the tip there is a sample port consisting of a hole covered by a small mesh size stainless steel screen. The screen section is easily removable for cleaning or replacement if required. A secondary sand-pack filter can be installed to reduce potential for clogging in fine sediments. Multiple (up to six) water sampling probes can be manifolded together to increase surface area, reduce clogging, and increase sampling rate.

3.0 List of Equipment

- Trident Probe
- Reference Probe
- Deck unit
- Laptop computer, w/ USB-serical adapter, AGIS and TridentTalk
- Long and short cables
- GPS antennae, handheld and cable
- Push poles/pins
- Power Inverter, power strip, 12V battery

- Manuals
- Sand packs, pre-cleaned sand
- Sample tubing and connectors
- Decon containers
- Peristaltic pumping system
- Tool Kit
- Log book
- Sample containers and labels

4.0 Sampling Procedure

4.1 Sensor sampling

In operation, the Trident probe can be deployed in several ways depending primarily on the depth of the site. In very shallow water (0-1 m), the operator simply walks or wades to sampling station, and manually pushes the probe to the desired depth. In water of moderate depths (1-10 m), the probe is easily deployed from a small boat using the push rod. A deployment frame can also be used in areas of high flow or armored bottom. It is important that the boat be well anchored to minimize lateral loading on the probe during the insertion.

Once on station with the probe inserted, data is collected from the conductivity and temperature sensors using the TridentTalk software. The software provides a display of the probe and reference temperature and conductivity signals, along with the GPS position. The software also automatically calculates and displays the probe vs. reference temperature and conductivity contrast. The data can then be reviewed in numeric format, or displayed spatially using the AGIS graphical information system software. The spatial AGIS display provides a capability for rapidly evaluating the most likely areas of groundwater discharge based on temperature and conductivity contrast. Typical operational procedure is summarized below:

- Secure boat on station using GPS
- Name “datafile” and “site ID” on TridentTalk
- Set averaging to 60 seconds or custom
- Lower Trident, adding poles as needed
- Insert Probe to desired depth in sediment
- Place GPS antennae on top pole
- If using liquid-tip, activate pump to purge screen volume
- Allow sensors to stabilize
- Click on “Log current data”
- Manually log values in log sheets/logbook including GPS position
- Refresh AGIS and view results
- Remove GPS antennae
- Recover Trident
- Retract push poles
- Decontaminate sampling system
- Move to next station

- Change “site ID” for next push on same transect or change “datafile” for new transect, then change “site ID”
- Repeat

4.2 Porewater and Surface Water Sampling

Porewater samples are collected using the water-sampling probe on the Trident connected by 1/16 inch inside diameter Teflon tubing to a low-flow peristaltic pumping system. Prior to sampling, all sampling components should be pre-cleaned in accordance with the procedures associated with the analysis to be performed on the samples. The probe is inserted to the desired sampling depth using the push-pole system. The screen and tube volume are purged using the pump, and the sample system is then used to fill the desired sampling bottles. Surface water samples are collected in the same manner with a secondary tube connected to the Trident Probe with the inlet at the desired distance above the sediment. Typical operational procedure is summarized below:

- Secure boat on station using GPS
- Lower Trident, adding poles as needed
- Insert Probe to desired depth in sediment
- Take GPS reading over top of pole
- Activate pump to purge screen and tube volume
- Collect desired samples to pre-cleaned bottles
- Log GPS and sample information in log sheets/logbook
- Recover Trident
- Retract push poles
- Decontaminate sampling system
- Move to next station
- Repeat

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Appendix B-2

Sediment Profile Imaging (SPI) System Quality Assurance Project Plan

Sediment Profile Imaging (SPI) System
Quality Assurance Project Plan

Prepared by:

Gemano & Associates, Inc.

May 4, 2009

TABLE OF CONTENTS
SPI Quality Assurance Project Plan (QAPP)

GERMANO & ASSOCIATES, INC. QUALITY ASSURANCE PROJECT PLAN

The purpose of this document is to describe the operation of the sediment profile imaging (SPI) system, the procedures used to collect SPI data, and the hazards associated with SPI camera deployment and operation.

SPI Camera Operation

The SPI camera system is attached to the hydrowire. The camera prism is mounted on an assembly that can be moved up and down by producing tension or slack on the winch wire. As the camera is lowered, tension on the wire keeps the prism' in the 'up' position. Once the camera frame contacts the bottom, slack on the wire allows the prism to vertically descend into the seafloor. The rate at which the optical prism penetrates into the sediments is controlled by a passive hydraulic piston. This allows the optical prism to descend at approximately 6 cm per second and minimizes disturbance to the sediment column. Once on the seafloor, the SPI camera is controlled by the descent of the prism assembly past a magnetic switch. When the magnetic switch is closed by contact with the prism assembly, photographs of the sediment column are taken at 5 and 15-second intervals from the time of switch contact. Two replicate images are collected per deployment, on taken 5 seconds after the camera contacts the seafloor and the other 15 seconds after the camera contacts the seafloor.

As the camera is raised off the bottom, a wiper blade automatically cleans any sediment off of the prism faceplate. The film is automatically advanced by a motor drive, the strobes are recharged, and the camera can be lowered for another replicate image.

When the camera is brought to the surface, the frame count is verified and the camera prism penetration is estimated from a penetration indicator that measures the distance the prism fell relative to the camera base. If penetration is minimal, weight packs can be loaded to give the assembly increased penetration. If penetration is too great, adjustable stops (which control the distance the prism descends) can be lowered, and "mud" doors can be attached to each side of the frame to increase the bearing surface.

Equipment

To conduct a SPI survey, the following equipment is needed:

SPI Camera Components

- Benthos Sediment Profile Camera
- 12 v Nicad Battery Packs
- 12 Kilogram Lead Weights (10 Sets)
- "Mud" Doors
- Nikon D200 Camera & Spare body
- Tool Kit
- Shackles, swivels and hardware

Positioning System

Research Vessel with winch and hydrowire having a minimum lifting capability of 150 kilos

Navigation system

Field Collections

At the beginning of each survey day, the time on the data logger mounted on the SPI camera will be synchronized with the navigation system clock. A Nikon digital SLR camera and a charged battery are loaded in the camera housing. Test shots are fired on deck at the beginning of each day to verify all internal electronics systems are working according to specifications.

Each SPI station replicate will be identified by the time recorded in the image file and the corresponding time and position recorded by the navigation system. A position will be recorded for each of the three replicate images taken at each SPI station. Redundant sample logs will be kept by the field crew. Information recorded in the field log includes:

- Time
- Date
- Station Location
- Replicate ID
- Frame Count
- Water Depth
- Penetration
- Observations on weather conditions, environmental conditions, or other pertinent observations
- Sampling Crew
- Time of arrival at vessel
- Time of survey commencement
- Time of survey conclusion
- Time departing vessel

Three replicate images will be taken at each SPI station. At regular intervals during each survey day, the frame counter is checked to make sure that the desired number of replicates have been taken. If images have been missed or the penetration depth is insufficient, then proper adjustments are made (e.g., weight is added to the frame) and additional replicates are taken.

To collect SPI data, the research vessel will be piloted to the target sampling location. Once within 20 feet of the target location, the SPI camera will be deployed. It is lowered to the seafloor until it lands on the bottom. Once on the bottom, an electronic trigger is activated signaling the camera to collect images 5 seconds after contact and 20 seconds after contact. Once the image set is acquired, the SPI camera is raised off the seafloor and lowered again to collect the remaining two replicate image sets.

The target production rate during the survey is approximately 50 stations per day, with three replicates per station and two images per each replicate being acquired. The rate of data acquisition will be affected by several variables including but not limited to: winch speed, efficiency of vessel positioning, weather conditions, water depth, and transit times.

Hazards Associated with SPI Surveying

The hazards associated with SPI data collections are primarily physical hazards. The SPI camera is large, heavy piece of equipment that is deployed from a research vessel or some other type of sampling platform. There are no chemical or environmental hazards associated with SPI data collection.

During assembly, mobilization and deployment of the SPI camera, the hazards are physical and mechanical in nature. The hazards include:

- Slips, Trips and Falls
- Pinching and crushing of body parts
- Strains and muscle pulls
- Exposure to the elements
- Falls overboard
- Drowning

Hazards Related to SPI Camera Assembly and Mobilization

Prior to field collections, the SPI camera is assembled and mobilized upon the research platform. The camera is shipped in large crates completely disassembled. Component parts are made of high-grade stainless steel, with individual pieces weighing between 2-50 kilos. These piece are bolted together to construct a high-strength steel frame assembly. During assembly all pieces are typically resting on the ground or platform and there are no overhead hazards. Potential hazards or risks during assembly are related to:

- the pinching of body extremeties while assembling the frame
- falls of component parts on fingers, hands, feet or toes
- slips, trips and falls of personnel, and
- back and muscle strain moving and lifting component parts.

Risks associated with these hazards are minimized by using safe and proper assembly techniques, hazard recognition, and workplace controls.

Hazards Related to SPI Camera Operation

As previously described, the SPI camera is deployed from a research platform and, once deployed, operates autonomously until retrieval.

In most operations, the SPI camera is lifted off the platform and articulated over the stern or side of the research vessel. The lifting and movement is typically accomplished using a winch system coupled with a davit, boom, or A-frame. The winch controls the raising and lowering of the SPI camera system and the A-frame or equivalent controls the articulation of the camera over the side of the platform. In some instances, the lifting point is fixed and the camera is manually guided to the water. The hazards inherent in this operation are the lifting and movement of the heavy SPI camera. Specifically hazards include:

- Falling or dropping of the SPI camera,
- Movement of the camera and trapping of personnel by the camera against a solid object such as a bulkhead, frame, or gunwhale
- Slipping while handling the camera
- Falling overboard while deploying the camera.

Furthermore, these factors can be exacerbated by weather and sea-state. The logistics of deploying the camera can be made more difficult by inclement weather such as wind and heavy rain along with platform motion caused by waves and sea-swell. These weather-related factors also cause the research platform to be less stable and increases the difficulty of conducting SPI operations. As the SPI camera must remain stationary on the seafloor for many seconds prior to retrieval, the ability of the platform to hold position influences both the success of the SPI sampling operation as well as the safety of the personnel conducting the SPI operations. If the vessel drifts while the SPI camera is on the seafloor, additional winch cable is paid out so that slack is continuously maintained until the camera is ready for retrieval.

During retrieval, the camera is winched upwards from the seafloor to the research vessel. The most hazardous portion of camera retrieval is the period of time from when the camera reaches the surface of the water until it is safely rested on the deck of the research platform. In calm seas and with an articulating lifting point, this is a safe and straightforward process. However, the difficulty of this maneuver increases with inclement weather conditions and heightened sea-state. In the event of heightened sea state, the camera is brought aboard using tag lines, with all personnel removed from the movements of the camera. Throughout the deployment and retrieval operations clear communication between the SPI camera operating personnel and personnel operating the winch/lifting device controls is maintained.

Physical Hazards

Gear deployment and retrieval present hazards because of the heavy weight of the sampling gear, its suspension above the deck, and the risk of accidental and premature closure. During typical field operations, several heavy pieces of equipment (hundreds of pounds) are used to collect field samples. This gear can includes the Sediment Vertical Profile System (SVPS), as well as a Gray-O'Hara box corer (0.06m 2), and a dual van Veen grab sampler (0.1 m^2). Safety pins are required to be in place on all pieces of gear, as appropriate, whenever the gear is inboard of the vessel rail. The triggering mechanism is always performed when the equipment is resting on a stable surface. All sampling gear is equipped with a ring by which the pin may be grasped for removal during deployment. If the gear or winch slips while a person's finger is inserted through this ring, the finger could be severed. Consequently, personnel are required to remove the safety pin only by grasping the outer edge of the ring between finger and thumb. During retrieval, at least one crew member watches for the appearance of the sampling gear at the water surface and alerts the winch operator. Failure to monitor gear retrieval and slow the winch upon surfacing can break the cable, cause loss of or damage the gear, or injure a crew member if the gear should fall or the cable end should snap. Personnel will be positioned on deck to safely bring the equipment aboard.

After repeated sampling, individual strands from the winch cable may break and project from the cable. Sampling personnel are instructed to avoid contact with the moving cable unless protected by work gloves. Periodically throughout the sampling cruise, the chief scientist inspects the cable for wear, especially where the wire is attached to the sampling gear. The chief scientist and safety officer are also responsible for periodic inspection of all shackles, pins, mousing, swivels, and thimbles to ensure the integrity of all points along the hydrowire. Likewise, all on-deck crew members are encouraged to periodically inspect these linkages. The winch drum, the blocks, and the area between the gear and the rail, deck, or other large equipment all represent significant pinching and crushing hazards. Personnel are instructed to keep their hands, feet, and clothing clear of these points. Lines, hoses, hatch covers, and mud on the deck all present tripping, slipping, and falling hazards. Every crew member should make an effort to keep the working surfaces of the deck clear and clean by coiling hoses and periodically washing the deck down with seawater to remove any mud left on deck from sampling operations.

Analysis of Sediment Profile Images

Thorough measurements of all physical parameters and some biological parameters are subsequently measured directly from the digital image files using a computer-image analysis system. The full color image analysis system can discriminate up to 16.7 million different shades of color, so subtle features can be accurately digitized and measured. Our software allows the measurement and storage of data on 21 different variables for each SPI image obtained. All data stored on disks are printed out on data sheets for editing by the principal investigator and as a hard-copy backup. All measured data are edited and verified by a senior-level scientist before being approved for final data synthesis, statistical analyses, and interpretation. Automatic disk storage of all parameters measured allows data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. In addition, the integration of the SPI analysis software with our database and GIS software allows any SPI measurement to be plotted (and contoured if desired) on a basemap of the survey area.

Specific measurement techniques for the SPI parameters measured are presented in the sections that follow.

Depositional Layer Thickness: Because of the camera's unique design, SPI has proven invaluable in detecting depositional layers ranging from 20 cm (the height of the SPI optical window) to 1 mm in thickness. During image analysis, the thickness of the newly-deposited layers is determined by measuring the linear distance between the pre- and post-disposal sediment water interface. Recently-deposited material is usually evident because of its unique optical reflectance and/or color relative to the underlying material representing the pre-disposal surface. Also, in most cases, the point of contact between the two layers and a textural change in sediment composition in the new layer are clearly visible, facilitating measurement of the thickness of the newly-deposited layer.

Sediment Type Determination: The sediment grain-size major mode and range are visually estimated from the photographs by overlaying a grain-size comparator which is at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the SPI camera. Seven grain-size classes are on this comparator: $\geq$ 4 phi, 4-3 phi, 3-2 phi, 2-1 phi, 1-0 phi, 0-(-)1 phi, < -1 phi. The lower limit of optical resolution of the photographic system is about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing our SPI estimates with grain-size statistics determined from laboratory sieve analyses.

Prism Penetration Depth: The SPI prism penetration depth is determined by:

1. Digitizing the entire area of sediment and dividing by the calibrated width of the image to get the average penetration depth; and,
2. measuring both the largest and smallest linear distance between the sediment-water interface and the bottom of the film frame.

The SPI analysis software automatically subtracts maximum and minimum values to determine the small scale boundary roughness value. All three values, (maximum, minimum, and average penetration depth) are included on the data sheets. Prism penetration is potentially a noteworthy parameter; if the number of weights used in the camera is held constant throughout a survey, the camera functions as a static-load penetrometer. Comparative penetration values from sites of similar grain-size give an indication of the relative sediment water content.

Surface Boundary Roughness: Surface boundary roughness is determined by measuring the vertical distance (parallel to the film border) between the highest and lowest points of the sediment-water interface. In addition, the origin of this small-scale topographic relief is indicated when it is evident (physical or biogenic). Boundary roughness is only accurately measured when the camera is level. In sandy sediments, boundary roughness can be a measure of sand wave height. On silt-clay bottoms, boundary roughness values often reflect biogenic features such as fecal mounds or surface burrows.

Mud Clasts: When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in SPI images. During analysis, the number of clasts is counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized (in SPI images, the oxidation state is apparent from their reflectance value; see section on Apparent Redox Potential Discontinuity Depth below). Also, once at the sediment-water interface, these sediment clumps are subject to bottom-water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6-12 hours (Germano, 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g. angular versus rounded, is also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano, 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

Apparent Redox Potential Discontinuity (RPD) Depth: Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying hypoxic or anoxic sediments. Surface sands washed free of mud also have higher optical reflectance than underlying muddy sands. These differences in optical reflectance are readily apparent in SPI images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally grey to black. The boundary between the colored ferric hydroxide surface sediment and underlying grey to black sediment is called the apparent redox potential discontinuity (abbreviated as the RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads, 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) which separates the positive Eh region of the sediment column from the underlying negative Eh region is called the Redox Potential Discontinuity or RPD. The exact location of this Eh=0 potential can only be determined accurately with microelectrodes; hence, the relationship between the change in optical reflectance, as imaged with the SPI camera, and the actual RPD can only be determined by making the appropriate *in-situ* Eh measurements. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD, and it is mapped as a mean value. In general, the depth of the actual Eh=0 horizon will be either equal or slightly shallower than the depth of the optical reflectance boundary. This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the Eh=0 horizon. As a result, the apparent mean RPD depth can be used as an estimate of the depth of pore water exchange, usually through pore water irrigation (bioturbation).

The depression of the apparent RPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore this parameter has a long time constant (Germano and Rhoads, 1984). The rebound in the apparent RPD is also slow (Germano, 1983). Measurable changes in the apparent RPD depth using the SPI optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients) which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. In sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS program for the U.S. Army Corps of Engineers, New England Division, SPI results have repeatedly documented a drastic reduction in apparent RPD depths at disposal sites immediately after dredged material disposal, followed by a progressive post-disposal apparent RPD deepening (barring further physical disturbance). Consequently, time series RPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean apparent RPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette *et al.*, 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly-reduced (lower-reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

Sedimentary Methane: At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in SPI images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total area covered by all methane pockets is measured.

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Appendix B-3

Benthic Macroinvertebrate Sampling Standard Operating Procedure

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Benthic Macroinvertebrate Sampling Standard Operating Procedure (SOP)

Rev. #: 0

Rev Date: 5/22/09

Approval Signatures

Prepared by: ______________________ Date: 5/22/09
Matt Frakelton

Reviewed by: ______________________ Date: 5/22/09
Dave Buys

I. Introduction

The following procedures describe the general methodologies that will be used in the field to sample the benthic macroinvertebrate community using a grab sampler and to collect co-located sediment grain size and total organic carbon (TOC) content samples.

II. Pre-Collection

Staff assigned the responsibility of collecting benthic macroinvertebrates and sediment grain size and TOC samples will be provided with the following information:

- Work documents (field sampling plan, health and safety plan, etc.);
- Water body name and site maps;
- Number of samples to be collected;
- Collecting and processing procedures;
- Special instructions (if any);
- Appropriate fisheries office contact; and
- Sampling permits and licenses.

III. Equipment

The following collection equipment and materials will be available, as required, during benthic sampling:

- Personal protective equipment (as required by the health and safety plan);
- Boat, engine, life jackets, anchors, buoys, and rigging;
- Sediment grab sampler;
- Mesh or sieve screen (standard U.S. no. 30);
- Sample jars, vials, and preservative (70% alcohol solution);
- Forceps and magnifying glass;
- Stainless steel mixing bowl, tray and scoop;
- Cleaning and decontamination materials;
- Insulated coolers with ice;
- Plastic sealable bags and indelible ink markers;

- Camera;
- Hand-held Global Positioning System (GPS) unit;
- Multi-parameter water quality meter;
- Flow meter;
- Survey rod; and
- Field notebook.

IV. Field Notes

Field notes will be recorded during sampling activities, and at a minimum, will include the following:

- Names of field crew and oversight personnel;
- General weather conditions;
- Date, time, and sample location (GPS if specified);
- Sampling technique and duration;
- General observations of benthic abundance and diversity;
- Substrate characterization and water quality; and
- Photograph number when pictures are taken (if necessary).

V. Collection Procedures

Benthic macroinvertebrate samples and sediment grain size and TOC samples will be collected using approved sampling techniques. The collection methods to be used to during the benthic community and associated sediment sampling efforts are presented below.

A. Benthic Macroinvertebrates

The following procedures describe the use of a sediment dredge to collect benthic macroinvertebrates:

1. The field crew will identify the proposed sample location using GPS or topographic landmarks and will anchor the boat securely so that it will not drift due to water or wind currents.

2. Water depth will be measured at each location.

3. Water quality data (temperature, dissolved oxygen, pH, specific conductance, turbidity, and water velocity) will be collected within 1 meter of the substrate surface. If sample locations are close together, these data will be recorded once for each general area.

4. At each sample location, the opened grab sampler will be lowered over the side of the boat and allowed to settle into bottom sediments. A hard pull on the rope will close the sediments inside the grab sampler.

5. The grab sampler will be retrieved into the boat and the sample contents will be emptied into a sieve.

6. The benthic samples will be sieved to isolate the benthic organisms. Organisms and sediment matrix will be hand transferred from the sieve to a labeled sample jar, and preserved in the field using 70% isopropyl alcohol.

7. This process will be repeated until the desired number of benthic samples per location is collected. Care will be taken so that successive grab sampling does not reoccur over previous sampled areas.

B. Sediment Grain Size and TOC

The following procedures describe the use of a sediment grab sampler to collect grain size and TOC samples:

1. Sediment sampling for grain size and TOC will be completed in conjunction with benthic community sampling at each location. Multiple grab samples will be composited to form one homogenized sediment sample. Care will be taken so that successive grab sampling does not reoccur over previous sampled areas.

2. From the composite sample, one grain size sample will be selected to fill half of a one-gallon sealable plastic bag, and one TOC sample will be selected to fill a 250 ml glass wide-mouth jar. Each container will be labeled. The TOC sample will be placed on ice in a cooler.

3. Sampling equipment will be cleaned between each sample location using an Alconox wash and a site water rinse.

VI. Sample Handling

The following identifies the temporary storage procedures that will be used to preserve benthic community and sediment grain size and TOC samples in the field prior to shipment to the laboratory:

1. Benthic organisms, and the remaining sediment matrix that is isolated after sieving, will be preserved in the field using 70% isopropyl alcohol.

2. Sediment TOC samples will be preserved on ice. Sediment grain size samples do not need chemical or thermal preservation, and will be stored at room temperature.

3. Samples will be labeled with sampling date and collection location, and will be counted to ensure that the correct number has been collected.

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Appendix B-4

Benthic Macroinvertebrate Processing Standard Operating Procedure

Infrastructure, environment, buildings

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Benthic Macroinvertebrate Processing Standard Operating Procedure (SOP)

Rev. #: 0

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Approval Signatures

Prepared by: ______________________ Date: 5/22/09

Matt Frakelton

Reviewed by: ______________________ Date: 5/22/09

Dave Buys

I. Introduction

The following procedures describe the general methodologies that will be used in the field to process (handle, pack, and ship) benthic macroinvertebrate and sediment grain size and total organic carbon (TOC) samples for laboratory analysis.

II. Equipment

The following equipment and materials will be available, as required, to process the benthic macroinvertebrate and sediment grain size and TOC samples:

- Insulated coolers with or without ice;
- Tape (duct, strapping, and clear packing);
- Sealable plastic bags;
- Indelible ink markers;
- Forms (chain-of-custody, custody seal, address label, and air-bill); and
- Field notebook.

III. Handling, Packing, and Shipping

The following identifies the procedures that will be used to handle, pack, and ship the benthic macroinvertebrate and sediment grain size and TOC samples:

A. Handling

1. All samples will be given a sample identification number that will be recorded in the field notebook, and that will correspond to the sample analysis, sampling date, and collection location.

2. Samples will be inspected to make sure that labeling is correct and that the sample containers are intact. Benthic community and TOC sample jars will be tightened and taped, if necessary. Sediment grain size samples will be double-bagged in sealable plastic bags, with the outer-seal duct-taped.

3. Chain-of-custody forms, custody seals, address labels, and air-bill forms will be initiated. A copy of the completed chain-of-custody form and air-bill form will be retained by the sampler.

B. Packing

1. Coolers used for transport will be duct-taped at the drain plug on the outside and inside of the cooler.

2. Benthic macroinvertebrate samples and sediment grain size samples will be placed upright in the bottom of separate coolers with cushioning materials placed on top. Sediment TOC samples will be placed in coolers with bags of ice (double-bagged with the outer seal duct-taped).

3. The completed chain-of-custody form will be placed into a plastic bag and duct-taped to the inside of the cooler lid.

4. The cooler will be closed and fastened with duct tape around the seam of the lid to prevent water leakage and with strapping tape around the entire cooler to prevent it from opening during transport.

5. A completed custody seal will be placed across the seam of the cooler lid. A completed address label will be placed on top of the cooler. Both will be taped-over using clear packing tape.

C. Shipping

1. Samples with holding time requirements will be shipped to the laboratory by hand or by express carrier within the specified time limits, or less, based on the date of sample collection. Samples that are fixed with preservative, or that do not have stringent holding times, will be delivered in a timely manner.

2. The laboratory will be notified of the shipment and will be contacted following the arrival date to ensure that delivery has occurred.